学　位　論　文　要　旨

Development of SWAT rice paddy module for basin scale assessment of pollutant transport
流域スケールにおける汚染物質の流出評価のための SWAT 稲作水田モジュールの開発

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The non-point source pollution from paddy fields has been reported as a particularly serious problem in water quality management in many Asian countries. In this regard, several models were developed for predicting the rice pollutants transport in field scale as well as in watershed scale. Besides monitoring approach, computer models have been applied and provided an effective alternative approach for predicting and assessing rice pollutant transport since the last two decades. However, modeling of rice pollutant transport has stayed a challenge due to the focusing in a single rice pollutant, unrepresentative paddy hydrology simulation and required much input data. Therefore, this research aimed to develop a comprehensive and standard rice paddy pollutant module which can simulate all representative paddy hydrology processes and rice pollutant fate and transport in watershed scale.

Several steps have been followed for the development of the rice paddy pollutant module. In first step, the PCPF-1@SWAT was selected and updated with SWAT model version 2012. The updated version of PCPF-1@SWAT model was renamed to PCPF-1@SWAT2012 and applied for simulating fate and transport of four rice herbicides namely mefenacet, pretilachlor, bensulfuron-methyl, and imazosulfuron in Sakura River watershed, Ibaraki, Japan. In the second step, the pothole module in the PCPF-1@SWAT2012 model was replaced by a paddy water balance and pesticide sub-modules of the rice paddy pollutant module. Furthermore, the sediment and nitrogen sub-modules of the rice paddy pollutant module were newly developed. Thirdly, the developed rice paddy pollutant module was then integrated into SWAT model version 2012 for predicting the fate and transport of the rice pollutant at watershed scale. For this purpose, the related input files and algorithms of water, pesticide, nitrogen and sediment routings of SWAT

model were modified. The coupled model named as SWAT Rice paddy Pollutant (SWAT-RP). Finally, the newly developed module was validated with prescribed datasets. The Sakura river watershed and Kose river watershed (Fukuoka, Japan) datasets were employed for verifying the paddy water balance and pesticide sub-modules performance. The mefenacet and pretilachlor data were used for pesticide simulations in the Sakura River and Kose River watersheds, respectively. The nitrogen and sediment sub-modules were initially validated with a lysimeter and paddy block datasets, respectively. At watershed scale, they were only performed uncalibrated simulations in the Sakura River watershed because of data limitation.

Results showed that the simulated water discharge and the rice herbicides concentrations by PCPF-1@SWAT2012 model in the Sakura River watershed were satisfactory. For the performance of the rice paddy pollutant module, the water discharge simulations during the calibration and validation periods were moderate (NSE = 0.72 and 0.63) at the Sakura River watershed and good (NSE=0.87 and 0.83) at Kose River watershed. Among the paddy water management parameters, only the paddy percolation rate showed significant relationship with the simulated water discharge in the two watersheds. The simulated mefenacet and pretilachlor concentrations had moderate accuracy (NSE = 0.73 and 0.78, respectively). In addition, the simulated mefenacet concentration using SWAT-RP and PCPF-1@SWAT2012 models had similar tendency with the observed data in the Sakura River watershed. The sensitive parameters to the simulated mefenacet concentrations were similar between the SWAT-RP and PCPF-1@SWAT2012 model in the Sakura river watershed indicating the good performance of the newly developed module. The simulated ammonium and nitrate concentration in paddy water in lysimeter were good (NSE = 0.88) and acceptable (NSE = 0.31), respectively. The predicted nitrate concentration had a very high uncertainty (r-factor = 7.26) compared to predicted ammonium concentration. Considering nitrogen modeling, the urea hydrolysis and denitrification rate constants were the most sensitive parameters to the simulated ammonium and nitrate concentrations, respectively. The sediment sub-module algorithms well simulated sediment transport in paddy block (NSE = 0.86). The sediment loss due to puddling operation was greatly dependent on the potential maximum sediment concentration and drainage water depth parameters. The uncalibrated simulated total inorganic nitrogen and sediment yield in the Sakura River watershed in 2007 were discussed.

In summary, the rice paddy pollutant module was developed and integrated with SWAT model for simulating pollutant fate and transport from both paddy and upland fields at watershed scale. The coupled model was successfully validated for rice pesticide simulation in two Japanese watersheds. The model must be validated its algorithms with rice sediment and nitrogen in watershed scale. Taking advantage of the SWAT-RP model regarding the standardized and comprehensive rice paddy pollutant module, SWAT-RP offers more flexible rice pollutants simulation in future studies. Therefore, the model will be a useful tool for potential risk assessment of water environment due to the increasing concern of the non-point source pollution from agriculture, and rice paddy in particular.